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Simulation study on cavity size for Si_3N_4 ceramics in process of MDSAM

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Abstract

In order to study the effect of machining parameters on machining efficiency, the size of ablation cavity for Si_3N_4 ceramics during process of micro-detonation of striking arc machining (MDSAM) is simulated. By means of simulation method and machining test, the cavity size can be achieved. Influences of machining parameters on cavity depth and diameter are computed and analyzed by single factor experiment. The results show that the experimental results are consistent with the simulation results as taking into account the loose deteriorative layer. Big working current, pulse width and small working distance can cause big machining efficiency. The nozzle radius should range from 1 mm to 1.4 mm. The research can present a method for precisely controlling the process of MDSAM. The simulation method can precisely calculate the cavity size and the process of MDSAM can be controlled more accurately.

Keywords: Micro-detonation of striking arc machining(MDSAM); cavity size; simulation; Si_3N_4 ceramics; machining parameters

1. Introduction

Engineering ceramics have excellent mechanical properties such as, high hardness, high thermal resistance and chemical stability, and could be applied to many areas [1]. Due to inherent hardness and brittle behaviors of ceramic materials, diamond wheel grinding was the most widely used machining method for ceramics. Moreover, grinding usually results in low material removal rates and high machining costs which may account for 60-90 % cost of product [2]. Researchers developed many non-traditional machining technologies to improve machining efficiency of ceramics, such as laser machining [3], EDM [4], plasma arc cutting [5] and high pressure abrasive water jet machining [6]. Some noticeable

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results are obtained, too. However, above technologies have their own limitations. The wide engineering application of above technologies can not be realized now.

The authors have proposed a novel machining technology for engineering ceramics, named as micro-detonation of striking arc machining (MDSAM) [7]. Machining experiments showed that this method could be used to machine different shapes stably and reliably, such as hole, plane surface, groove, cylinder, complex shaped surface, and so on. During the machining process, the plasma jet with high temperature and high pressure is sprayed out from the nozzle of micro-detonation generator. In single pulse width duration, as the plasma jet is applied on the material surface, the surface temperature exceeds the boiling point of the material causing rapid melting or vaporization and an ablation cavity is generated.

For MDSAM is a rough machining technology, high machining efficiency is the most important target. The machining efficiency can be represented by the volume of ablation cavity in single pulse. In this paper, the cavity size of Si_3N_4 in process of MDSAM is studied by means of simulation and experiment. The influence laws of parameters on cavity shape are given to analyze the material removal ability of parameters.

2. Simulation and machining test for size of ablation cavity

2.1. Simulation

Si_3N_4 ceramics is selected as experimental materials in computing of cavity size. Si_3N_4 ceramics is wildly used in thermal machines, cutting tools, fire resisting materials and other demanding environments owing to its high strength, high temperature properties, high hardness and good corrosion resistance.

In MDSAM, there are four parameters to influence MDSAM machining process. They are working current I, diameter of micro-generator nozzle R, pulse width T and the distance between nozzle and specimen surface L. The parameters were fixed as follows: I = 80 A, T = 80 ms, L = 3 mm and R=1 mm.

The decomposing temperature point of Si_3N_4 is 1900 ℃. While machining, the plasma jet sprays out from nozzle and applies on the specimen surface. The surface absorbs a large amount of heat and the temperature of ceramic may reach the decomposing point. At the end of single pulse, the temperature reaches the highest value 12100 ℃ at the centre of ablation cavity. The theoretical size of ablation cavity is 1.12 mm in radial direction and 0.508 mm in thickness direction, as shown in Fig.1a.

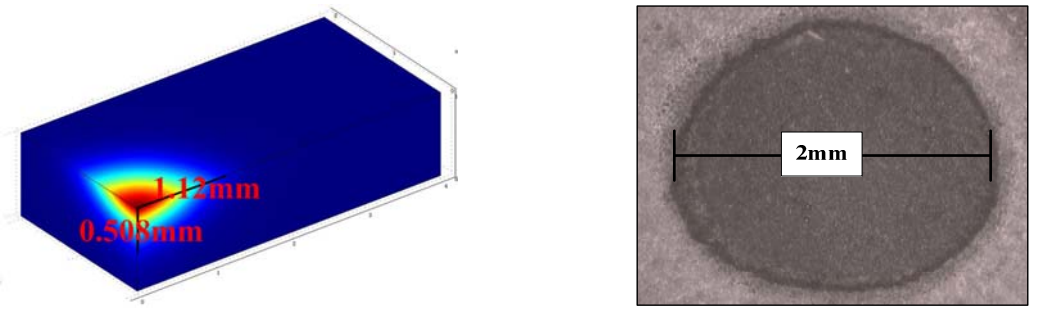

Fig.1.(a) Simulation result of size of 1/4 cavity;(b) machining result of a cavity

2.2. Machining test

The same machining parameters as simulation example are employed in machining test. Fig.1b shows the macro-morphology of cavity after single pulse machining. The cavity is in shape of a spherical cap and its cross section is approximately circle. The cavity size is measured as dimension of 2 mm and depth of 0.18 mm.